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ORNL Contaminant Scoping Survey

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SUMMARY

As a part of the ORNL Remedial Action Program, a preliminary contaminant scoping survey was conducted for groundwater of the several solid waste storage areas, chemical waste pits, seeps, and sediments of White Oak Lake. A total of 31 wells, 4 seeps, and 3 sediment samples were collected. Analyses included metals, total toxic organics, and radionuclides. Results from these samples will be used to characterize and assess ORNL remedial action needs and priorities.

Introduction

Implementation of the remedial action program at ORNL will be a complex process, beginning with identification of sites requiring corrective actions and ending with final certification for their closure. Compliance with several state and federal laws as well as DOE orders is an integral part of this task. To enhance this process there are several general "big picture" activities which must be done to characterize and assess overall remedial action needs and to assist in establishment of priorities.

The purpose of this document is to report groundwater and lake sediment contamination within and around chemical and solid waste storage facilities on the Oak Ridge National Laboratory site. This report discusses the sampling procedures, analytical parameters and methodologies, and the contamination levels of radionuclides, metals, and priority pollutants by sample and site. To obtain a basis for evaluating the magnitude of the hazardous chemical contamination in the environment around these sites, groundwater was obtained from wells of solid waste storage areas, pits, trenches, seeps and sediments from White Oak Lake. The sample analyses will be used for scoping purposes: general regulatory comparisons, remedial action budget estimates, and other planning.

Sampling Methods

Wells

Wells sampled for groundwater were selected on the merits of adequate water column, potential for compositing with other samples, and location relative to suspected groundwater movement. Three wells were sampled in SWSA 3 (wells 301, 302, and 303). All other wells in this burial ground were either dry or were fitted with permanent instruments. A map of SWSA 3 and the well locations are depicted in Figure 1. There is a slight elevation gradient from the southwest (highest) to the northeast (lowest) across SWSA 3. These wells most likely represent optimum sample points with respect to groundwater movement. Seven wells were sampled in SWSA 4 (wells 180, 181, 182, 186, 190, 191, and 195). The approximate locations of the wells are illustrated in Figure 2. The drop in elevation across SWSA 4 is about 14 m (247 m to 233 m MSL) from northeast to southwest. Expected groundwater movement is to an ephemeral stream along the southern boundary of the site. Wells 186, 191, and 195 are located in the vicinity of the stream. In addition to wells, two nonspecified and one specified (S2) seeps were sampled. Six wells were sampled in SWSA 5 (wells 456, 436, T64-1, 454, 159, and 161). A nonspecified seep was also sampled (Figure 3). Wells 436 and T64-1 are approximately 60 m from Melton Branch. Wells 161, 159, and 454 are in the area of transuranic waste storage. Six wells (wells 272, 279, 305, 371, 380, and 382) were sampled in SWSA 6 (Figure 4). SWSA 6 is bordered on the southeast by White Oak Lake. Many wells in this area (SWSA 6) were either dry or damaged. Those wells sampled probably represent the only wells amenable for adequate groundwater collection. Wells sampled in the pit and trench area (Figure 5) were selected relative to past histories

of leakage. For example, well 95 is southwest of Pits 2 and 4, both with histories of Ru-106 leakage to the west. Wells 98 and 99 are east and downslope of Pit 3, which leaked toward the east. Wells 84 and 96 are located in a drainage system downslope and west of Pit 5, which has no history of visual leakage. Well T6-7 is positioned downslope of Pit 6. Because of fissures in the substrate, this pit began to leak one month after initial use. In order to eliminate stagnant water in the lower portion of the well which may not be representative of the formation water conditions, each well was purged prior to sample collection. The volume of water purged was determined from the measured distance from the bottom of the well to the static water level. One to three volumes of water in the wells were removed, and the wells were allowed to recharge before sample collection. Samples were collected in a period of drought, such that some wells did not recharge to the original volume. Water was removed with the aid of a peristaltic pump, except in wells greater than 25 feet deep. Deep wells were purged with a hand bail. The hand bail (bucket) was washed between samples with 0.1 N HNO_3, rinsed in distilled water, and dried with paper towels. Three liters of water were collected from each well in one-liter-size polyethylene containers; two were adjusted to 0.1 N nitric acid, and the third remained as collected. Each container was placed into a polyethylene bag for handling purposes, transported to the Health Physics field laboratory, surveyed for level of radioactive contamination, and transferred to the Analytical Chemistry laboratory for analysis.

Seeps

In some Solid Waste Storage Areas (SWSA) there are active seeps. Seep groundwater was collected from reservoirs which were dug in the seep streams

and allowed to discharge several days before sample collection. One designated seep (Seep 2) and two nonspecified seeps were sampled in SWSA 4 (Figure 2). A nonspecified seep was also sampled in SWSA 5 (Figure 3). Three liters of water were collected from these areas and two were acidified as the well samples. Sample containers were placed in polyethylene bags and surveyed for level of radioactive contamination prior to transfer to Analytical Chemistry.

Sediment Sampling

White Oak Lake and White Oak Creek have been used to dilute and contain low-level radioactive liquid wastes discharged from ORNL. The lake floor sediments constitute a major source of elemental and radionuclide accumulation and retention. To account for the amount and distribution of contaminants, core samples were taken from the upper, middle, and lower sections of the lake. These areas were determined from previous survey studies, namely Lomenick and Gardiner (1965), outlining "hot" spots of radionuclide concentration. Figure 6 illustrates the lake boundary and location of the coring sites.

Core samples were taken by forcing an aluminum tube, 7.62 cm in diameter, to a depth of 40 centimeters or greater below the lake bed (floor) surface. The sample tube was capped at both ends to prevent any mixing or loss of core material. The core sample was then tagged and stored in a freezer to facilitate removal of the sediment profile from the tube. In a frozen state, the core was extruded from the tube and subdivided into two centimeter segments. Each segment was preserved in sealed aluminum cans and

marked according to sample number and depth. Laboratory analyses of these samples included radionuclide, elemental (metals), and chemical pollutant detection (as outlined in appendix for groundwater).

Analytical Procedures for Groundwater and Sediment Samples

Chemical analyses used to characterize sediment and groundwater samples were performed by the ORNL Analytical Chemistry Division. The methods used are predominately those described in Test Methods for Evaluating Solid Waste, Physical/Chemical Methods, SW-846, second edition, published July 1982 by the USEPA Office of Solid Waste and Emergency Response, Washington, D.C. (USEPA 1982) and Methods for Chemical Analysis of Water and Wastes, EPA-600/4-79-020, revised March 1983, published by USEPA Environmental Monitoring and Support Laboratory, Office of Research and Development, Cincinnati, Ohio (USEPA 1983).

Concentrations of radionuclides were determined using solid state alpha and beta detectors. Analyses of gamma-emitting radionuclides were conducted using high-resolution detectors. The detectors were shielded from extraneous background and were calibrated for the respective sample geometries using certified mixtures of gamma-emitting radionuclide standard solutions from the National Bureau of Standards (NBS).

Total elemental concentrations were determined by digesting a 1-g sample (dry weight at 110°C overnight) with a 1:1 mixture of concentrated nitric acid and concentrated hydrofluoric acid. After bringing to dryness, the residue was taken up in 12% nitric acid, and elemental concentrations were determined by ICP spectroscopy. Thus, this digestion procedure precludes

the analysis of mercury because the element is lost on volatilization. In addition to ICP analysis, cadmium and lead were determined by polarography for low-level (< 1 ppm) detection. Appendix A lists the elemental constituents, methodologies, and the respective detection limits.

The EP toxicity test was conducted as outlined by EPA method 1310 (USEPA 1982). The concentrations of metals in the EP extract were determined by EPA methods 7061, 7081, 7131, 7191, 7421, 7270, 7741, and 7761 in USEPA (1982) and inductively coupled plasma (ICP) spectroscopy, method 200.7 in USEPA (1983). The concentrations of pesticides and PCB levels in the EP extracts were determined by method 8080 (USEPA 1982). Herbicides were analyzed by liquid chromatography instead of gas chromatography. The total toxic organics (TTO) in the EP extracts were determined using method 8240 (USEPA 1983) or pentane extraction for the volatile organic compounds and method 8270 (USEPA 1982) for the semivolatile compounds. Appendix B lists all the priority pollutants covered in the aforementioned methodologies.

Data Compilation and Summary

This section describes the contamination levels and patterns found in groundwater and sediment samples taken from the various waste storage areas and White Oak Lake and creek near ORNL. Analytical treatment of field samples was divided and summarized according to three types, namely radionuclides, elemental, and priority pollutants (as described in the previous analytical section). Data have been compiled to present a broad picture of the degree and extent of contamination for all sites collectively and for the major chemical and solid waste storage areas. Summary tables include mean, median, and maximum concentrations by site for each of the

analytical constituents. These summations exclude samples failing to provide detectable concentrations for the given element or compound and its analytical methodology. Thus, an assessment based on the summarized data should represent a worst-case condition for each site and contaminant recorded. The distribution of site contamination was treated by noting the percent of sample sites demonstrating a detectable concentration.

Radionuclides - Groundwater

Results identified low-level concentrations for at least one of the major radionuclides tested (i.e., Strontium-90, Cesium-137, and Cobalt-60) among all sites. Table 1 provides the measured radionuclide concentrations above the detection limits set by the analytical procedure for all groundwater samples. Table 2 summarizes the median, mean, and maximum radionuclide concentrations for each of the major site division. These figures constitute an average of only those well sites indicating detectable amounts of radioelement activity. In every case, median values were much less than site means, which demonstrates the impact of a few high concentrations in inflating the overall averages. The percent of wells by site with greater than detectable concentrations is given in Table 3. In more than half the site divisions, less than one third of the wells sampled showed some measurable concentrations for Strontium-90, Cesium-137, and Cobalt-60, collectively. Strontium-90 represented the highest concentrations and was the only element to appear on all sites.

Metals - Groundwater

Analytical results of metal concentrations of well groundwater and seep samples are given in Table 4. Summary information is given in Table 5 including mean and maximum values reported by site and element.

Priority Pollutants

A total of 118 toxic organics were tested following EPA guidelines and procedures. Results showed no traceable quantities except for dimethyl phthalate in sample 134, (well T64-1) on SWSA 5. This amount was just below the detection limit of 10 µg/ml for the analytical procedure employed.

Duplicate Well Samples

Some initial well samples were taken without properly purging the well according to RCRA guidelines. Rather than discard these groundwater samples, it was decided to note the differences in the analytical results with subsequent samples from the same wells following proper well purging. Table 6 compares the before and after purging results for three radionuclides of duplicate well samples. Findings indicate no substantial difference in relative magnitude between samples. Strontium-90 values were consistently greater after purging, but within the error margins given for the stated concentrations and testing procedure. Samples taken without well purging showed some tendency to retain Cesium-137, probably due to greater clay suspension brought about by a longer well life.

Duplicate comparisons of elemental concentrations from the same wells are given in Table 7. The presence and abundance of elements in paired observations appear to mimic each other without distinguishable differences, and characteristically, to identify the well and site from which they were collected.

White Oak Lake - Sediment

Radionuclides

Three cores of the sediment profile of White Oak Lake were taken in the lower, middle, and upper lake sections where radionuclide concentrations were found to be highest in earlier surveys. Table 8 lists the various radionuclides and concentrations by core sample and depth.

Core 1 was collected approximately 550 m east of White Oak Lake dam, near the north shore of the lake (Figure 6). Data are expressed in Bq/kg (wet weight). Concentrations of Cobalt-60 were uniformly distributed in the top 36 cm of sediments, averaging $2.3 \times 10^3 \pm 9.5$ Bq/kg. Maximum concentration was 7.6×10^3 Bq/kg at the 36-40 cm depth (Figure 7). Strontium-90 concentrations showed a more gradual increase with increasing depth (Figure 8), and a maximum concentration of 1.0×10^4 Bq/kg (270 µCi/kg) at the 32-36 cm depth. Cesium-137 concentrations increased with depth (Figure 9), with a maximum concentration of 3.8×10^5 Bq/kg (10.26 µCi/kg) at the 44-48 cm depth. The core sample was not sufficiently deep to determine that this was the depth of maximum contamination. Tritium was detected and uniformly reported as < 500 Bq/kg (13.5 µCi/kg).

Core 2 was collected approximately 325 m east of White Oak Dam (Figure 6), approximately 50 m from the north lakeshore. Core collection was less successful than for Core 1, with a maximum depth of 36 cm. The maximum Cobalt-60 concentrations were observed between 16 and 28 cm (Figure 10), with a maximum radioactivity of 7.5×10^3 Bq/kg (202 µCi/kg, decreasing to 1.4×10^3 Bq/kg (37.8 µCi/kg) in the 28-32 cm depth. Strontium-90

concentration increased abruptly at 16 cm (3.4×10^4 Bq/kg), decreasing to 7.8×10^3 Bq/kg at 32 cm (Figure 11). Cesium-137 concentrations increased gradually with peaks at 16-20 and 32-36 cm increments. Activities were 3.6×10^5 Bq/kg (9.72 µCi/kg) and 7.6×10^5 Bq/kg (20.52 µCi/kg), respectively (Figure 12). Because the core was not sufficiently deep, it is not clear that this is the maximum concentration. Tritium was detected and uniformly reported as < 500 Bq/kg.

Core 3 was collected approximately 110 m east of White Oak Lake dam (Figure 6), and 50 m from the north lake shoreline. The depth of the sample was 68 cm. Maximum Cobalt-60 concentration (4.3×10^4 Bq/kg) was observed at the 8 to 12 cm depth, decreasing abruptly in deeper increments (Figure 13). Two peaks of Strontium-90 concentrations were noted (Figure 14) at 32-36 cm and 52-56 cm depths, 2.4×10^4 Bq/kg and 1.7×10^4 Bq/kg, respectively. Cesium-137 concentration was greatest (6.2×10^5 Bq/kg) at the 40-44 cm depth (Figure 15). Concentrations decreased abruptly in subsequent increments. Tritium was detected at all depths and was uniformly reported as < 800 Bq/kg.

Elemental (metals)

Results of metal analysis on sediment samples from White Oak Lake have not been completed.

Priority Pollutants

None of the toxic organics analyzed for in this study were found in any core samples.

REFERENCES

Lomenick, T. F. and D. A. Gardiner. 1965. The occurrence and retention of radionuclides in the sediments of White Oak Lake. Health Physics 2:567-77.

U.S. Environmental Protection Agency (USEPA). 1982. Test Methods for Evaluating Solid Waste, Physical/Chemical Methods, SW-846, 2nd ed. Solid Waste and Emergency Response, Washington, D.C.

U.S. Environmental Protection Agency (USEPA). 1983. Methods for Chemical Analysis of Water and Wastes. EPA-600/4-79/020. USEPA Environmental Monitoring and Support Laboratory, Office of Research and Development, Cincinnati, Ohio.

Webster, D. A. 1976. A Review of Hydrologic and Geologic Conditions Related to the Radioactive Solid Waste Burial Grounds at Oak Ridge National Laboratory, Tennessee. U.S. Geological Survey, Open-File Report No. 76-727.

APPENDIX A

Elemental Constituents and Detection Limits

Symbol	Common Name	Procedure	Detection Limit ug/ml
Ag	Silver	ICP	<.05
Al	Aluminum	ICP	<.2
As	Arsenic	ICP	<.1
B	Boron	ICP	<.08
Ba	Barium	ICP	<.02
Be	Berylium	ICP	<.002
Ca	Calcium	ICP	
Cd	Cadmium	ICP	<.005
Co	Cobalt	ICP	<.01
Cr	Chromium	ICP	<.04
Cu	Copper	ICP	<.02
Fe	Iron	ICP	
Hf	Hafnium	ICP	<.4
Ga	Gallium	ICP	<.3
Li	Lithium	ICP	<.2
Mg	Magnesium	ICP	
Mn	Manganese	ICP	<.005
Mo	Molybedenium	ICP	<.04
Na	Sodium	ICP	
Ni	Nickel	ICP	<.06
P	Phosphorus	ICP	<.3
Pb	Lead	ICP	<.2
Sb	Antimony	ICP	<.2
Se	Selenium	ICP	<.2
Si	Silicon	ICP	<.2
Sr	Strontium	ICP	<.005
Ti	Titanium	ICP	<.02
V	Vanadium	ICP	<.01
Zn	Zinc	ICP	<.02
Zr	Zirconium	ICP	<.02
Cd	Cadmium	Polar	<1.0 ppb
Pb	Lead	Polar	<2.0 ppb

APPENDIX B

Total Toxic Organics, Reference Codes, and Detection Limits

NPDES No.	EPA No.	CAS#	Compound	Detection Limit (ug/L)
(11A)	(21A)	88-06-2	2,4,6-trichlorophenol	<10
(08A)	(22A)	59-50-7	p-chloro-m-cresol	<10
(01A)	(24A)	95-57-8	2-chlorophenol	<10
(02A)	(31A)	120-83-2	2,4-dichlorophenol	<10
(03A)	(34A)	105-67-9	2,4-dimethylphenol	<10
(06A)	(57A)	88-75-5	2-nitrophenol	<20
(07A)	(58A)	100-02-7	4-nitrophenol	<50
(05A)	(59A)	51-28-5	2,4-dinitrophenol	<50
(04A)	(60A)	534-52-1	4,6-dinitro-2-methylphenol	<20
(09A)	(64A)	87-86-5	pentachlorophenol	<50
(10A)	(65A)	108-95-2	phenol	<10
		65-85-0	benzoic acid	<50
		95-48-7	2-methylphenol (o-cresol)	<10
		108-39-4	4-methylphenol (p-cresol)	<10
	(531A)	95-95-4	2,4,5-trichlorophenol	<10
(34B)	(52B)	87-68-3	hexachlorobutadiene	<10
(35B)	(53B)	77-47-4	hexachlorocyclopentadiene	<10
(38B)	(54B)	78-59-1	isophorone	<10
(39B)	(55B)	91-20-3	naphthalene	<10
(40B)	(56B)	98-95-3	nitrobenzene	<10
(41B)	(61B)	62-75-9	N-nitrosodimethylamine	<50
(43B)	(62B)	86-30-6	N-nitrosodiphenylamine	<20
(42B)	(63B)	621-64-7	N-nitrosodipropylamine	<20
(13B)	(66B)	117-81-7	bis(2-ethylhexyl)phthalate	<10
(15B)	(67B)	85-68-7	benzyl butyl phthalate	<10
(26B)	(68B)	85-74-2	di-n-butyl phthalate	<10
(29B)	(69B)	117-84-0	di-n-octyl phthalate	<10
(24B)	(70B)	84-66-2	diethyl phthalate	<10
(25B)	(71B)	131-11-3	dimethyl phthalate	<10
(05B)	(72B)	56-55-3	benzo(a)anthracene	<50
(01B)	(01B)	83-32-9	acenaphthene	<10
(04B)	(05B)	92-87-5	benzidine	<50
(46B)	(08B)	120-82-1	1,2,4-trichlorobenzene	<10
(33B)	(09B)	118-71-1	hexachlorobenzene	<10
(36B)	(12B)	67-72-1	hexachloroethane	<10
(11B)	(18B)	111-44-4	bis(2-chloroethyl)ether	<10
(16B)	(20B)	91-58-7	2-chloronaphthalene	<10
(20B)	(25B)	95-50-1	1,2-dichlorobenzene	<10
(21B)	(26B)	541-73-1	1,3-dichlorobenzene	<10
(22B)	(27B)	106-46-7	1,4-dichlorobenzene	<10
(23B)	(28B)	91-94-1	3,3'-dichlorobenzidine	<50
(27B)	(35B)	121-14-2	2,4-dinitrotoluene	<10
(28B)	(36B)	606-20-2	2,6-dinitrotoluene	<10
(30B)	(37B)	122-66-7	1.2-dipyenylhydrazine	<20

Appendix B continued.

NPDES No.	EPA No.	CAS#	Compound	Detection Limit (ug/L)
(31B)	(39B)	206-44-0	fluoranthene	<10
(17B)	(40B)	7005-72-3	4-chlorophenyl phenyl ether	<10
(14B)	(41B)	101-55-3	4-bromophenyl phenyl ether	<10
(12B)	(42B)	39638-32-9	bis(2-chloroisopropyl)ether	<10
(10B)	(43B)	111-91-1	bis(2-chloroethoxy)methane	<10
(01P)	(89P)	309-00-2	aldrin	<10
(10P)	(90P)	60-57-1	dieldrin	<10
(06P)	(91P)	57-74-9	chlordane	<10
(07P)	(92P)	50-29-3	4,4'-DDT	<10
(08P)	(93P)	72-55-9	4,4'-DDE	<10
(09P)	(94P)	72-54-9	4,4'-DDD	<10
(11P)	(95P)	115-29-7	Endosulfan I (alpha)	<10
(12P)	(96P)	115-29-7	Endosulfan II (beta)	<10
(13P)	(97P)	1031-07-8	Endosulfan Sulfate	<10
(06B)	(73B)	50-32-8	benzo(a)pyrene	<10
(07B)	(74B)	205-99-2	benzo(b)fluoranthene (3,4)	<10
(09B)	(75B)	207-08-9	benzo(k)fluoranthene	<10
(18B)	(76B)	218-01-9	chrysene	<10
(02B)	(77B)	208-96-8	acenaphthylene	<10
(03B)	(78B)	120-12-7	anthracene	<10
(08B)	(79B)	191-24-2	benzo(ghi)perylene	<20
(32B)	(80B)	86-73-7	fluorene	<10
(44B)	(81B)	85-01-8	phenanthrene	<10
(19B)	(82B)	53-70-3	dibenzo(a,h)anthracene	<20
(37B)	(83B)	193-39-5	indeno(1,2,3-cd)pyrene	<20
(45B)	(84B)	129-00-0	pyrene	<10
		62-53-3	aniline	<10
		100-51-6	benzyl alcohol	<10
		106-47-8	4-chloroaniline	<10
		132-64-9	dibenzofuran	<10
		91-57-6	2-methylnaphthalene	<10
		88-74-4	2-nitroaniline	<10
		99-09-2	3-nitroaniline	<10
		100-01-6	4-nitroaniline	<10
(14P)	(98P)	72-20-8	Endrin (<0.2 ECD)	<10
(15P)	(99P)	7421-93-4	Endrin Aldehyde	<10
(16P)	(100P)	76-44-8	Heptachlor	<10
(17P)	(101P)	1024-57-3	Heptachlor Epoxide	<10
(02P)	(102P)	319-84-6	Alpha-BHC	<10
(03P)	(103P)	319-85-7	Beta-BHC	<10
(05P)	(105P)	319-86-8	Delta-BHC	<10
(04P)	(104P)	58-89-9	Gamma-BHC (lindane) (<2 ECD)	<10
(03V)	(04V)	71-43-2	benzene	<4.4
(06V)	(06V)	56-23-5	carbon tetrachloride	<2.8
(07V)	(07V)	108-90-7	chlorobenzene	(<5)*
(15V)	(10V)	107-06-2	1,2-dichloroethane	<2.8

Appendix B continued.

NPDES No.	EPA No.	CAS#	Compound	Detection Limit (ug/L)
(27V)	(11V)	71-55-6	1,1,1-trichloroethane	<3.8
(14V)	(13V)	75-34-3	1,1-dichloroethane	<4.7
(28V)	(14V)	79-00-5	1,1,2-trichloroethane	<5
(23V)	(15V)	79-34-5	1,1,2,2-tetrachloroethane	<6.9
(09V)	(16V)	75-00-3	chloroethane (gas)	ND
(10V)	(19V)	110-75-8	2-chloroethylvinyl ether	ND
(11V)	(23V)	67-66-3	chlcroform	<1.6
(16V)	(29V)	75-35-4	1,1-dichloroethene	<2.8
(26V)	(30V)	156-60-5	trans-1,2-dichloroethene	<1.6
(17V)	(32V)	78-87-5	1,2-dichloropropane	<6
(18VT)	(33V)	542-75-6	trans-1,3-dichloropropene	(<5)*
(18VC)		542-75-5	cis-1,3-dichloropropene	<5
(19V)	(38V)	100-41-4	ethylbenzene	(<5)*
(22V)	(44V)	75-09-2	methylene chloride	<2.8
(21V)	(45V)	74-87-3	methylchloride (gas)	ND
(20V)	(46V)	74-83-9	methylbromide (gas)	ND
(05V)	(47V)	75-25-2	bromoform	<4.7
(12V)	(48V)	75-27-4	dichlorobromomethane	<2.2
(30V)	(49V)	75-69-4	trichlorofluoromethane	ND
(08V)	(51V)	124-48-1	chlorodibromomethane	(<5)*
(24V)	(85V)	127-18-4	tetrachloroethene	<4.1
(25V)	(86V)	108-88-3	toluene	(<5)*
(29V)	(87V)	79-01-6	trichloroethene	<1.9
(31V)	(88V)	75-01-4	vinyl chloride (gas)	ND
(25P)		8001-35-2	toxaphene (<5 ECD)	<10
		72-43-5	methoxychlor (<8 ECD)	<10
			2,4-D (HPLC)	<10
		93-72-1	2,4-5 T (Silvex) (HPLC)	<10

ND = the detection limit for these compounds has not been determined.
()* = estimated detection limit.
Detection limits are for gas chromatography/mass spectrometry unless otherwise specified.
ECD = Electron Capture Detector.
HPLC = High Performance Liquid Chromatography.

Table 1. Radionuclide concentrations (Bq/l) of groundwater well and seep samples taken from ORNL solid waste storage areas.*

Sample #	Site	Well #	SR-90	CS-137	CO-60	SB-125
101	SWSA 3	301	1.2			
102	SWSA 3	302	27.			
103	SWSA 3	303	4.3			
104	SWSA 4	182	5.5			
105	SWSA 4	181	9.6			
106	SWSA 4	180	.89			
107	SWSA 4	186	37.	.31		
108	SWSA 4	191	760.	.21		
109	SWSA 4	190	84.			
110	SWSA 3	301	7.9			
111	SWSA 3	302	28.			
112	SWSA 3	303	6.3			
113	SWSA 4	191	1000.			
114	SWSA 4	186	76.			
115	SWSA 4	195	25.			
116	Pit 4W	95	3.2		120.	
117	Pit 4E	84	.36		23.	2.5
118	Pit 3W	124	1.4		4.4	
119	Pit 3	99	.50		.83	
120	Pit 3	98	.34		1.8	
121	Pit 2E	96			47.	
122	Pit 7W	WT7-7	.23		.32	
123	Pit 7W	WT7-3	.49		.40	
124	Pit 6W	T6-7	54.	180.	2.7	
125	SWSA 6	279	.06			
126	SWSA 6	382	.09		.2	
127	SWSA 6	371	.09			
128	SWSA 6	272	.49	5.5	.24	
129	SWSA 6	380		2.5		
130	SWSA 6	305	.1	.61		
131	SWSA 5	454	8.2	.26		
132	SWSA 5	159	520.	.39		
133	SWSA 5	161	18.	.35		
134	SWSA 5	T64-1	13.	.13		
135	SWSA 5	436	120.	.99		
136	SWSA 5	465	11.	5.8		
137	SWSA 4	Seep	84.			
138	SWSA 4	Seep	42.			
139	SWSA 4	Seep	800.	.87		
140	SWSA 5	Seep	13000.			

*There were no detectable quantities of tritium (H^3).

Table 2. Summary of radionuclide concentrations (Bq/l) for groundwater well and seep samples by site association.

		SR-90	CS-137	CO-60
SWSA 3	m	7.1		
	mean	12.5		
	max	28.		
SWSA 4	m	59.	.31	
	mean	244.	.46	
	max	1000.	.87	
SWSA 5	m	18.	.37	
	mean	1956.	1.3	
	max	13000.	5.8	
SWSA 6	m	.09	2.5	.22
	mean	.17	2.9	.22
	max	.49	5.5	.24
Pits & Trenches	m	.49	180.	4.4
	mean	7.6	180.	26.7
	max	54.	180.	120.
All	m	8.1	.61	2.7
	mean	441.	15.2	21.9
	max	13000.	180.	120.

m = median.
max = maximum value for any observation in the subset.

Table 3. Percent of wells by site containing measurable concentrations of Strontium-90, Cesium-137, and Cobalt-60.

Site	SR-90	CS-137	CO-60
SWSA 3	100	0	0
SWSA 4	100	33	0
SWSA 5	100	14	0
SWSA 6	83	50	33
Pits & Trenches	89	11	100
All	95	33	28

Table 4. Elemental concentrations (µg/ml) of groundwater well and seep samples taken from ORNL waste storage sites.

Sample #	Well #	Site	Ag	Al	As	B	Ba	Be	Ca	Cd	Co
101	301	SWSA 3					.19		80.	.008	
102	302	SWSA 3					.052		77.	.013	
103	303	SWSA 3				.18	.056		74.	.01	
104	182	SWSA 4					.098		56.		
105	181	SWSA 4					.150		81.		
106	180	SWSA 4		.24			.23		65.		
107	186	SWSA 4		2.7		.17	.47		170.	.0092	.085
108	191	SWSA 4		.045		.2	.21		96.		
109	190	SWSA 4					.16		110.		
110	301	SWSA 3					.07		110.		
111	302	SWSA 3					.05		85.		
112	303	SWSA 3				.12	.067		97.	.012	
113	191	SWSA 4		.3		.24	.21		100.		
114	186	SWSA 4		.28		.19	.25		160.		.019
115	195	SWSA 4				.14	.091		110.		
116	95	Pit 4W					.059		53.		.1
117	84	Pit 4E		.23			.048		26.		.015
118	124	Pit 3W					.063		85.		
119	99	Pit 3					.2		88.		
120	98	Pit 3		.3			.062		96.		.026
121	96	Pit 2E					.066		84.		.065
122	WT7-7	Pit 7W		.6			.054		56.	.0076	
123	WT7-3	Pit 7W					.094		100.		
124	T6-7	Pit 6W		.57			.16		3.4	.0054	.012
125	279	SWSA 6		.47			.11		43.		
126	382	SWSA 6		.6			.25		20.		.028
127	371	SWSA 6		.59			.3		90.		
128	272	SWSA 6		.4			.1		76.		
129	380	SWSA 6		.57			.14		25.		
130	305	SWSA 6			.4		26.				
131	454	SWSA 5		2.5		.29	1.4		120.	.01	.036
132	159	SWSA 5		.3		.78	.28		100.		.011
133	161	SWSA 5		.57		.85	.2		79	.0082	.025
134	T64-1	SWSA 5		8.9			.46	.0023	36.	.013	.017
135	436	SWSA 5		1.5			.16		21.		
136	465	SWSA 5		.23		.51			.52	.0052	
137	Seep	SWSA 4				.17	.19		120.		
138	Seep	SWSA 4		.68		.82	.22		98.	.013	
139	Seep	SWSA 4		2.7		.12	.51	.0027	56.		.015
140	Seep	SWSA 5					.025		42.		

Table 4. continued.

Sample	Well #	Site	Cr	Cu	Fe	Ga	Li	Mg	Mn	Mo	Na
101	301	SWSA 3			1.0			4.9	.13	.11	.86
102	302	SWSA 3			1.6			8.8	.15	.097	.83
103	303	SWSA 3			.094			7.2	.084	.053	.69
104	182	SWSA 4			.84			8.7	.095		1.20
105	181	SWSA 4			.043			7.7			1.5
106	180	SWSA 4			.58			4.2	.077	.12	5.8
107	186	SWSA 4	.051	.19				22.	6.0	.054	30.
108	191	SWSA 4		.045	21.			20.	2.0		13.
109	190	SWSA 4			14.			18.	1.1	.082	5.5
110	301	SWSA 3			4.3			7.1	.17		.93
111	302	SWSA 3			1.2			10.0	.11	.062	.85
112	303	SWSA 3			.31			9.1	.19	.07	.7
113	191	SWSA 4			5.8			23.0	.94		15.0
114	186	SWSA 4			7.0			25.0	2.8		33.0
115	195	SWSA 4			1.5		1.3	24.0	6.4		21.0
116	95	Pit 4W			.14			6.0	.15		230.0
117	84	Pit 4E			.31			3.9	1.3		160.
118	124	Pit 3W			.12			9.8	.042		41.0
119	99	Pit 3		.048	27.			14.	.042		8.2
120	98	Pit 3		.025	2.4			8.2	1.1		8.1
121	96	Pit 2E		.022	.57			17.	.58		120.
122	WT7-7	Pit 7W			.6			4.6	.036	.099	.76
123	WT7-3	Pit 7W		.06			6.	.1		12.	
124	T6-7	Pit 6W		.087	140.			1.2	.74		2.7
125	279	SWSA 6			13.			4.3	.64	.11	3.0
126	382	SWSA 6			27.			9.6	9.1		4.4
127	371	SWSA 6			1.2			12.0	.13		5.9
128	272	SWSA 6			1.2			4.2	.076	.13	1.3
129	380	SWSA 6			1.1			4.0	.27		2.1
130	305	SWSA 5			240.			5.3	.36	.43	
131	454	SWSA 5			230.			15.0	1.2	.2	15.
132	159	SWSA 5		.025	21.			16.0	2.5		15.
133	161	SWSA 5			51.			15.0	1.2	.2	15.
134	T64-7	SWSA 5		.05	10.			10.	1.1	.047	2.6
135	436	SWSA 5		.11	.74			6.9	1.1		1.7
136	465	SWSA 5		.035	2.5			.16	.042		420.
137	Seep	SWSA 4			4.1			24.	2.3		29.
138	Seep	SWSA 4		.11	1.7		.27	22.	.86	.054	28.
139	Seep	SWSA 4			7.9			13.	2.3		15.
140	Seep	SWSA 5			.11			7.7	.15		100.

Table 4. continued.

Sample #	Well #	Site	Ni	P	Pb	Sb	Se	Sl	Sr	Ti	V
101	301	SWSA 3						2.5	.098		.013
102	302	SWSA 3		.5				2.2	.093		.02
103	303	SWSA 3						1.8	.1		.017
104	182	SWSA 4						1.6	.043		.019
105	181	SWSA 4						2.8	.059		.019
106	180	SWSA 4						9.1	.033		.013
107	186	SWSA 4	.1					6.4	.18		.041
108	191	SWSA 4						4.1	.18		.037
109	190	SWSA 4	.23					5.1	.14		.032
110	301	SWSA 3						2.8	.14		.017
111	302	SWSA 3		.4				2.8	.10		.022
112	303	SWSA 3						2.0	.13		.021
113	191	SWSA 4						3.9	.18		.042
114	186	SWSA 4	.069					4.2	.22		.046
115	195	SWSA 4						3.6	.2		.044
116	95	Pit 4W	.12					4.3	.059		.014
117	84	Pit 4E		.43				3.2	.033		.018
118	124	Pit 3W						2.1	.077		.023
119	99	Pit 3						7.3	.13		.028
120	98	Pit 3						3.9	.084		.021
121	96	Pit 2E	.067					2.9	.13		.034
122	WT7-7	Pit 7W		.33				3.4	.034		.012
123	WT7-3	Pit 7W						4.7	.068		.015
124	T6-7	Pit 6W						6.7	.0059		
125	279	SWSA 6		.33				3.6	.036		.012
126	382	SWSA 6		.31				5.3	.09		.023
127	371	SWSA 6		.47				6.3	.11		.023
128	272	SWSA 6		.37				4.4	.033		.014
129	380	SWSA 6						4.1	.043		.011
130	305	SWSA 6					1.3	5.2			
131	454	SWSA 5	.077	12.		.25	.22	13.	.16		.046
132	159	SWSA 5						4.6	.18		.032
133	161	SWSA 5		1.1				4.8	.11		.029
134	T64-1	SWSA 5		2.	.81			7.9	.078		.034
135	436	SWSA 5		2.5				3.4	.037		.022
136	465	SWSA 5			.24						.017
137	Seep	SWSA 4						3.7	.2		.038
138	Seep	SWSA 4						6.6	.37		.036
139	Seep	SWSA 4	.37					5.6	.078		.025
140	Seep	SWSA 5						1.5	.046		.015

Table 4. continued.

Sample	Well #	Site	Zn	Zr	Cd*	Pb*
101	301	SWSA 3	7.8		3.0	5.0
102	302	SWSA 3	6.8		3.0	10.0
103	303	SWSA 3	4.0		3.0	3.0
104	182	SWSA 4	2.1			
105	181	SWSA 4	2.7			
106	180	SWSA 4	8.3			15.
107	186	SWSA 4	3.9			60.
108	191	SWSA 4	.39			
109	190	SWSA 4	5.6			20.
110	301	SWSA 3	2.6			3.0
111	302	SWSA 3	4.5			10.0
112	303	SWSA 3	5.4		5.0	
113	191	SWSA 4	.12			5.0
114	186	SWSA 4	.24			2.0
115	195	SWSA 4	.065			5.0
116	95	Pit 4W	.05			
117	84	Pit 4E	.046			
118	124	Pit 3W	.30			
119	99	Pit 3	.86			10.
120	98	Pit 3	.59			5.
121	96	Pit 2E	.13		1.0	5.
122	WT7-7	Pit 7W	7.1			
[illegible]	WT7-3	Pit 7W	.35			
[illegible]	T6-7	Pit 6W	1.4			7.
125	279	SWSA 6	8.6			5.
126	382	SWSA 6	.078			
127	371	SWSA 6	.03			5.
128	272	SWSA 6	9.5			10.
129	380	SWSA 6	.11			10.
130	305	SWSA 6	27.			20.
131	454	SWSA 5	27			55.
132	159	SWSA 5	1.1			30.
133	161	SWSA 5	14.			50.
134	T64-1	SWSA 5	3.3		2.	305.
135	436	SWSA 5	.25			40.
136	465	SWSA 5	.095			
150.						
137	Seep	SWSA 4				5.
138	Seep	SWSA 4	.52		6.	20.
139	Seep	SWSA 4				
140	Seep	SWSA 5				

*reported in ppm.

Table 5. Mean and maximum values of elemental concentrations (µg/ml) for groundwater by site.

Element	SWSA 3		SWSA 4		SWSA 5	
	Mean	Max	Mean	Max	Mean	Max
Ag						
Al			1.05	2.7	2.33	8.9
As						
B	.15	.18	.26	.82	.61	.85
Ba	.08	.19	.23	.51	.42	.46
Be			.0027	.0027	.0023	.0023
Ca	87.16	110.	101.83	170.	56.93	120.
Cd	.01	.013	.01	.013	.01	.013
Co			.04	.085	.02	.036
Cr			.051	.051		
Cu			.12	.19	.06	.11
Fe	1.42	4.3	5.86	21.	45.05	51.
Ga						
Hf			.06	.075		
Li			.79	.27		
Mg	7.85	10.0	17.63	25.	10.11	16.
Mn	.14	.19	2.26	6.4	3.44	18.
Mo	.08	.11	.08	.12	.21	.38
Na	.81	.93	16.5	33.	80.9	420.
Ni			.19	.37	.08	.077
P	.45	.5			4.4	12.
Pb					.53	.81
Sb					.25	.25
Se					.22	.22
Si	2.35	2.8	4.73	9.1	5.87	13.
Sr	.11	.14	.16	.37	.10	.18
Ti						
V	.02	.022	.03	.046	.03	.046
Zn	5.13	7.6	2.39	8.3	7.62	27.
Zr						
Cd*	3.0	5.	6.	6.	2.	2.
Pb*	6.2	10.	16.5	60.	105.	305.

*reported in ppm.

Table 5. continued.

Element	SWSA 6 Mean	SWSA 6 Max	Pits & Trenches Mean	Pits & Trenches Max	All Sites Mean	All Sites Max
Ag						
Al	.53	.6	.43	.6	1.17	8.9
As						
B					.34	.85
Ba	.22	.4	.09	.2	.20	.47
Be					.0026	.0027
Ca	46.67	90.	65.71	100.	75.37	170.
Cd			.0065	.0076	.01	.013
Co	.028	.028	.04	.065	.04	.085
Cr					.051	.051
Cu			.046	.087	.068	.19
Fe	47.25	240.	19.02	140.	21.6	240.
Ga						
Hf	.11	.11			.071	.11
Li					.785	1.3
Mg	6.57	12.	7.85	17.	10.99	25.
Mn	2.45	9.1	.45	.74	1.65	9.1
Mo	.22	.43	.089	.099	.13	.43
Na	3.34	5.9	73.11	230.	35.09	230.
Ni			.09	.12	.15	.37
P	.37	.47	.38	.43	1.73	2.5
Pb					.53	.81
Sb					.25	.25
Se	1.3	1.3			.7	1.3
Si	4.82	6.3	4.28	7.3	4.45	9.1
Sr	.06	.11	.07	.13	.11	.37
Ti						
V	.02	.023	.02	.034	.03	.046
Zn	7.55	27.	1.20	7.1	4.24	27.
Zr						
Cd*			1.0	1.0	3.28	6.
Pb*	10.	20.	6.75	10.	31.07	305.

*reported in ppm.

Table 6. Comparison of radionuclide concentrations (Bq/l) from duplicate well samples taken with and without purging.

Site	Well	SR-90		CS-137		CO-60	
		Before	After	Before	After	Before	After
SWSA 3	#301	1.2	7.9	<.2	<.2	<.2	<.2
SWSA 3	#302	27.	28.	<.1	<.1	<.1	<.1
SWSA 3	#303	4.3	6.3	<.1	<.1	<.1	<.1
SWSA 4	#186	37.	76.	.31	<.1	<.2	<.2
SWSA 4	#191	760.	1000.	.21	<.1	<.2	<.2

Table 7. Comparison of elemental concentrations (µg/ml) from duplicate well samples with or without purging.

	SWSA 3					
	Well #301		Well #302		Well #303	
Sample #	101[a]	110[b]	102[a]	111[b]	103[a]	112[b]
Element						
Ag						
Al						
As						
B						
Ba	.19	.07	.052	.05	.056	.067
Be						
Ca	80.	110.	77.	85.	74.	97.
Cd	.008		.013		.01	.012
Co						
Cr						
Cu						
Fe	1.0	4.3	1.6	1.2	.094	.31
Ga						
Hf						
Li						
Mg	4.9	7.1	8.8	10.	7.2	9.1
Mn	.13	.17	.15	.11	.084	.19
Mo	.11		.097	.062	.053	.07
Na	.86	.93	.83	.85	.69	.7
Ni						
P			.5	.4		
Pb						
Sb						
Se						
Si	2.5	2.8	2.2	2.8	1.8	2.0
Sr	.098	.14	.093	.10	.1	.13
Ti						
V	.013	.017	.02	.022	.017	.021
Zn	7.8	2.6	6.8	4.5	4.0	5.4
Zr						
Cd	3.0		3.0		3.0	5.0
Pb	5.0	3.0	10.0	10.0	3.0	

[a]Groundwater samples obtained without purging.
[b]Groundwater samples collected after removing three well volumes.

Table 7. continued.

	SWSA 4			
	Well #186		Well #191	
Sample #	107[a]	114[b]	108[a]	113[b]
Element				
Ag				
Al	2.7	.28	.45	.3
As				
B	.17	.19	.2	.24
Ba	.47	.25	.21	.21
Be				
Ca	170.	160.	96.	100.
Cd	.0092			
Co	.085	.019		
Cr	.051			
Cu	.19		.045	
Fe		7.	21.	5.8
Ga				
Hf		.056		.041
Li				
Mg	22.	25.	20.	23.
Mn	6.	2.8	2.	.94
Mo	.054			
Na	30.	33.	13.	15.
Ni	.1	.069		
P				
Pb				
Sb				
Se				
Si	6.4	4.2	4.1	3.9
Sr	.18	.22	.18	.18
Ti				
V	.041	.046	.037	.042
Zn	3.9	.24	.39	.12
Zr				
Cd				
Pb	60	2.0		5.

[a]Groundwater samples obtained without purging.
[b]Groundwater samples collected after removing three well volumes.

Table 8. Radionuclide concentrations (Bq/kg) of White Oak Lake core samples by depth.

Core	Sample	Depth (cm)	SR-90 x 10^3	CS-137 x 10^4	CO-60 x 10^3	H-3	SE-75	EU-152	EU-154	CS-134	K-40
1	141	0-4	1.4	3.5	2.9		64.	290.	220.	120.	
	143	4-8	1.7	3.9	3.0				230.	130.	280.
	145	8-12	1.5	5.4	3.3			230.	190.		280.
	147	12-16	3.3	8.4	2.0						130.
	149	16-20	2.3	9.8	2.2						410.
	151	20-24	1.4	8.8	2.3						240.
	153	24-28	2.5	9.6	.86				570.		190.
	155	28-32	3.4	14.	1.3						
	157	32-36	10.	33.	2.8				490.		
	159	36-40	7.5	25.	7.6						
	161	40-44	5.5	27.	5.4						
	163	44-48	4.3	38.	1.1						
2	165	0-4	1.6	3.5	3.3				160.		
	167	4-8	2.1	3.8	3.4				220.	100.	190.
	169	8-12	3.2	3.7	3.0			180.	210.		260.
	171	12-16	5.8	12.	4.2				92.		430.
	173	16-20	35.	36.	7.3						
	175	20-24	20.	22.	7.5						730.
	177	24-28	7.1	20.	7.5						
	179	28-32	5.3	40.	1.4						350.
	181	32-36	7.8	76.							340.
	183	36-40									
3	185	0-4	3.4	3.6	3.2		69.	250.	190.	53.	230.
	187	4-8	3.0	4.2	4.0				160.		
	189	8-12	4.7	4.8	43.			430.	340.		450.
	191	12-16	5.3	4.2	3.3			230.	330.		250.
	193	16-20	9.1	5.5	2.7				280.		
	195	20-24	9.0	5.7	2.2						210.
	197	24-28	10.	10.	2.8						170.
	199	28-32	12.	17.	2.1				110.		510.
	201	32-36	24.	27.	5.1						
	203	36-49	16.	40.	2.0						
	205	40-44	15.	62.							
	207	44-48	9.3	48.							
	209	48-52	4.6	2.7							
	211	52-56	17.	13.	3.0						400.
	213	56-60	2.6	.25							
	215	60-64	1.7	.021							430.
	217	64-68	1.7	.0072							250.

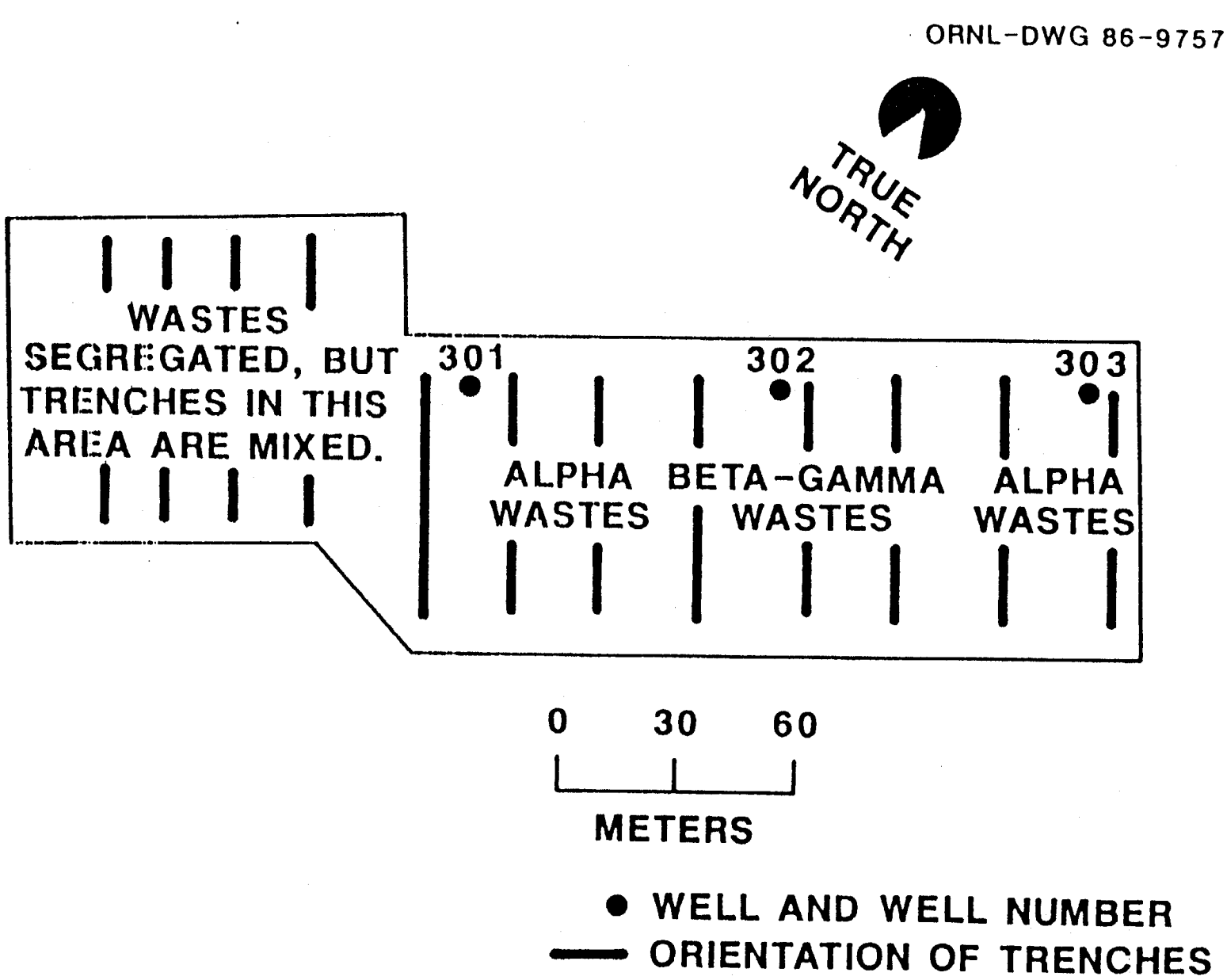

Figure 1. Location of wells sampled in SWSA 3.

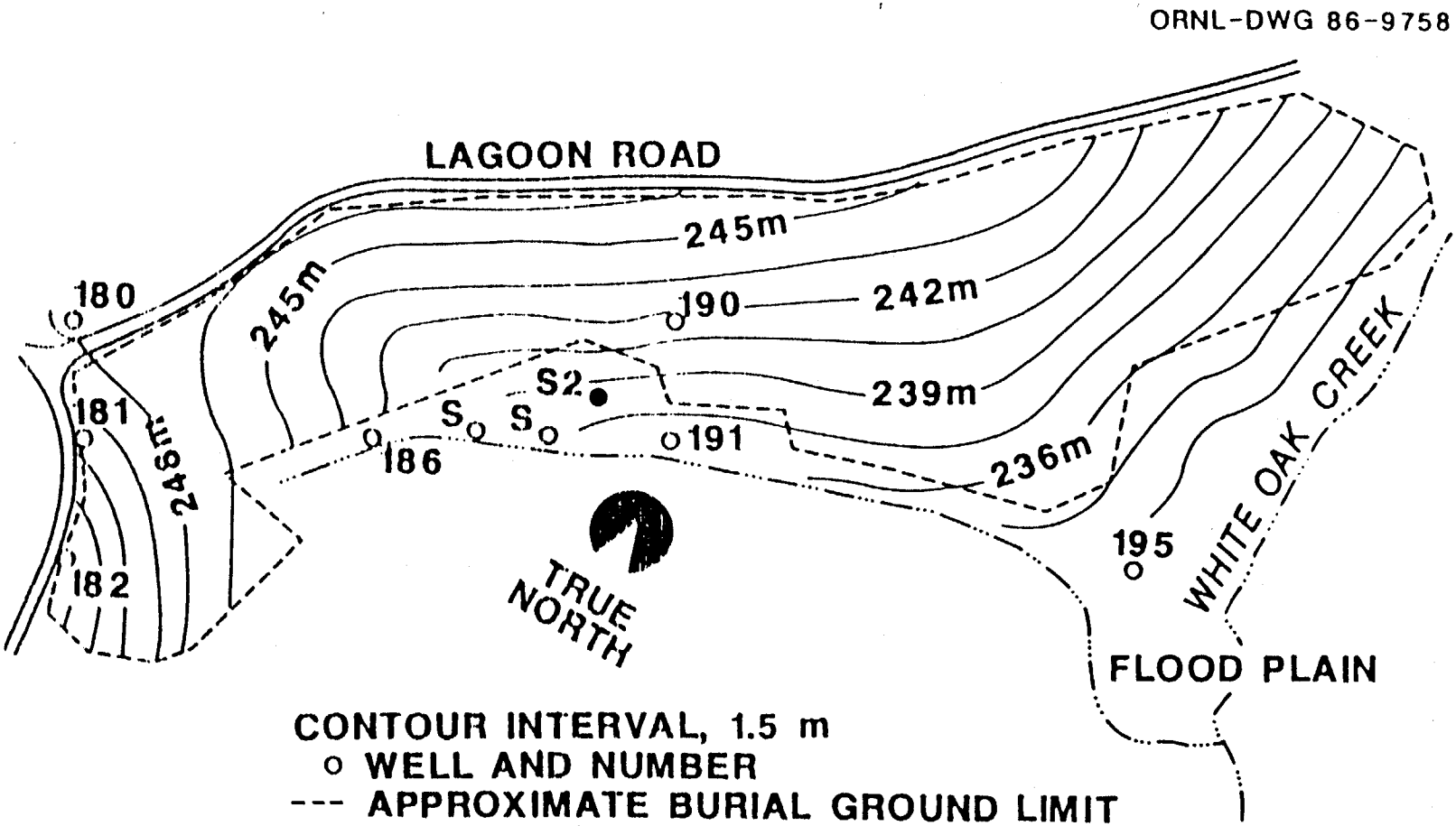

Figure 2. Location of wells and seeps sampled in SWSA 4.

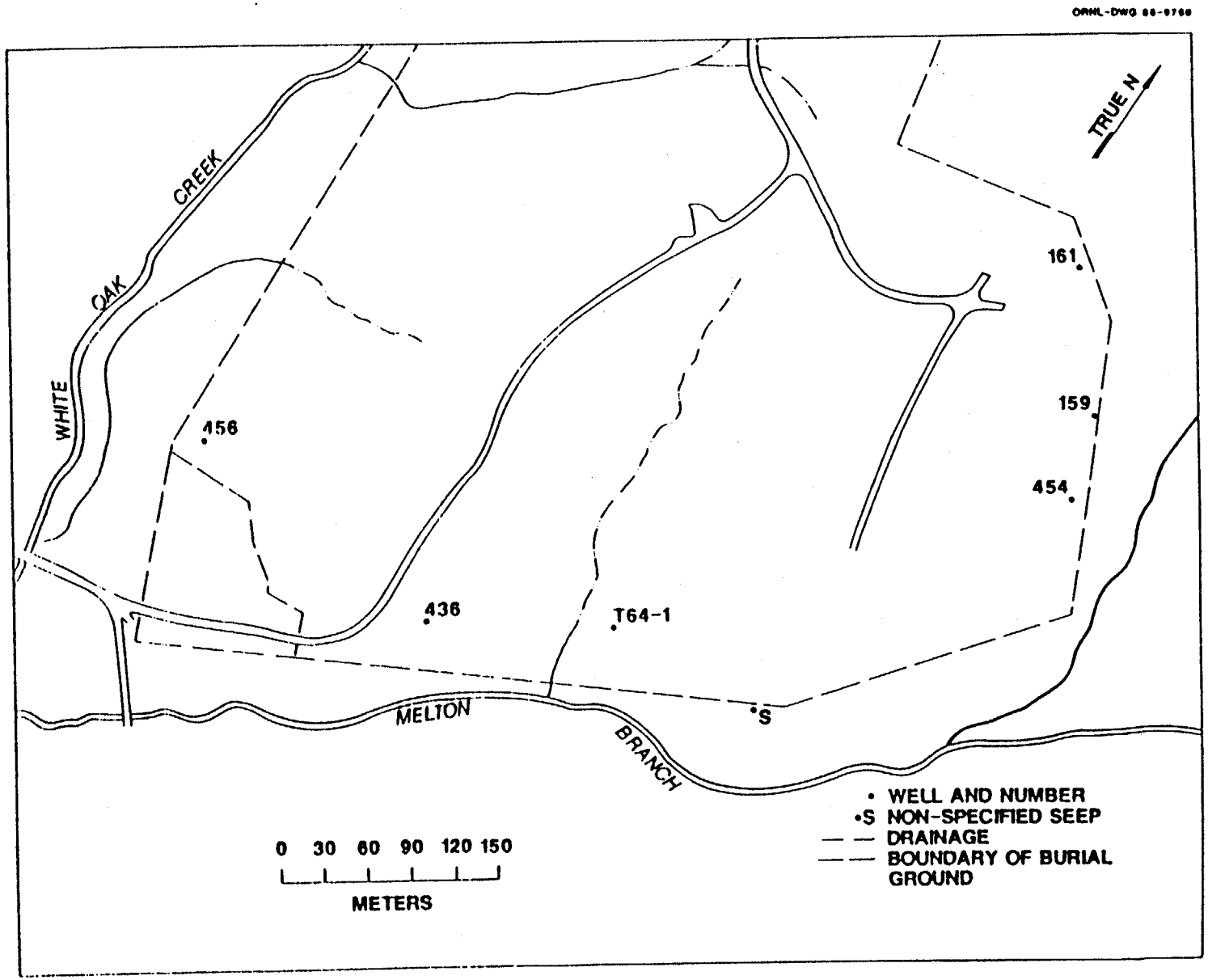

Figure 3. Location of wells and a single seep sampled in SWSA 5.

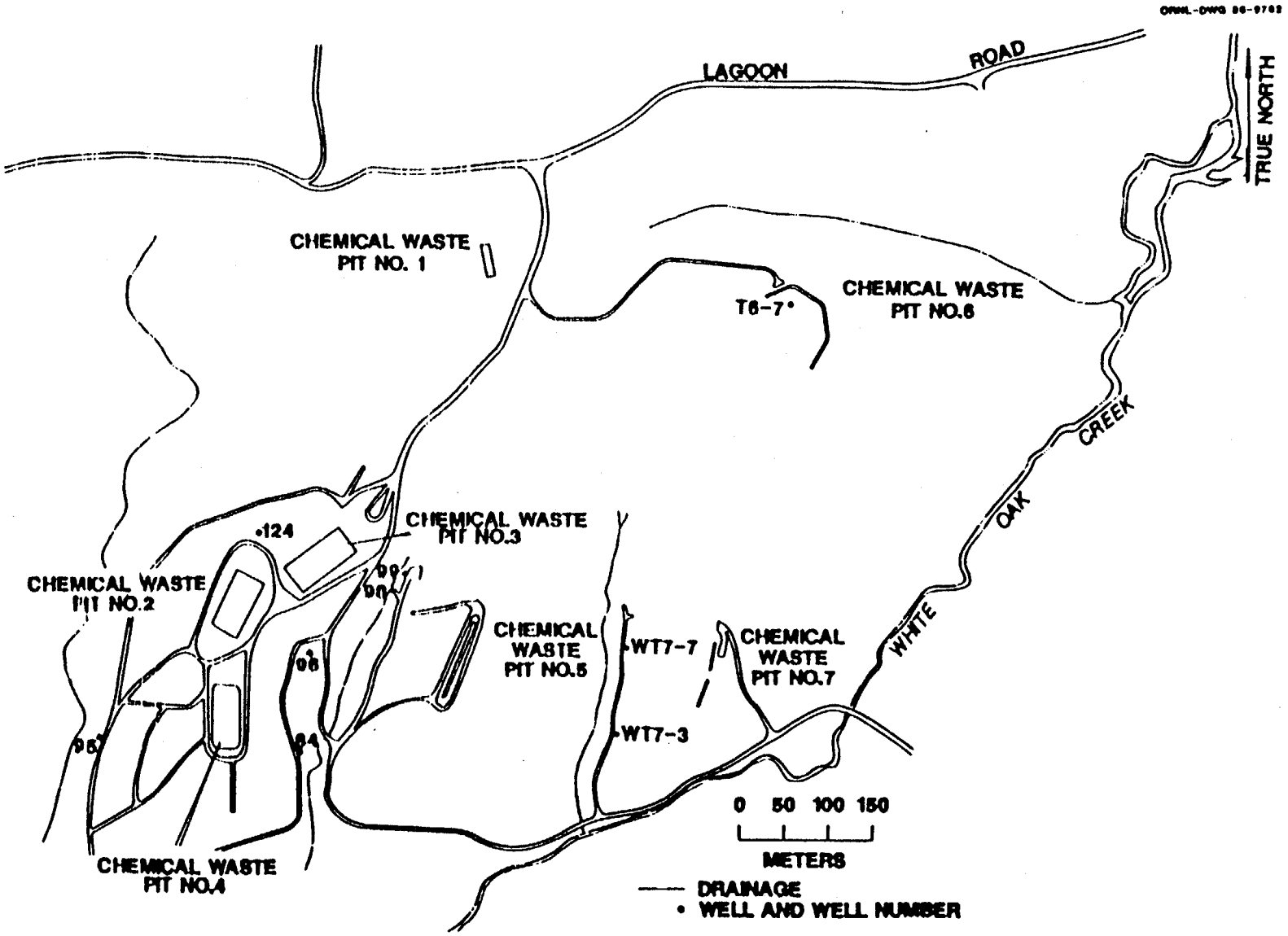

Figure 5. Location of wells sampled near the Pits and Trenches.

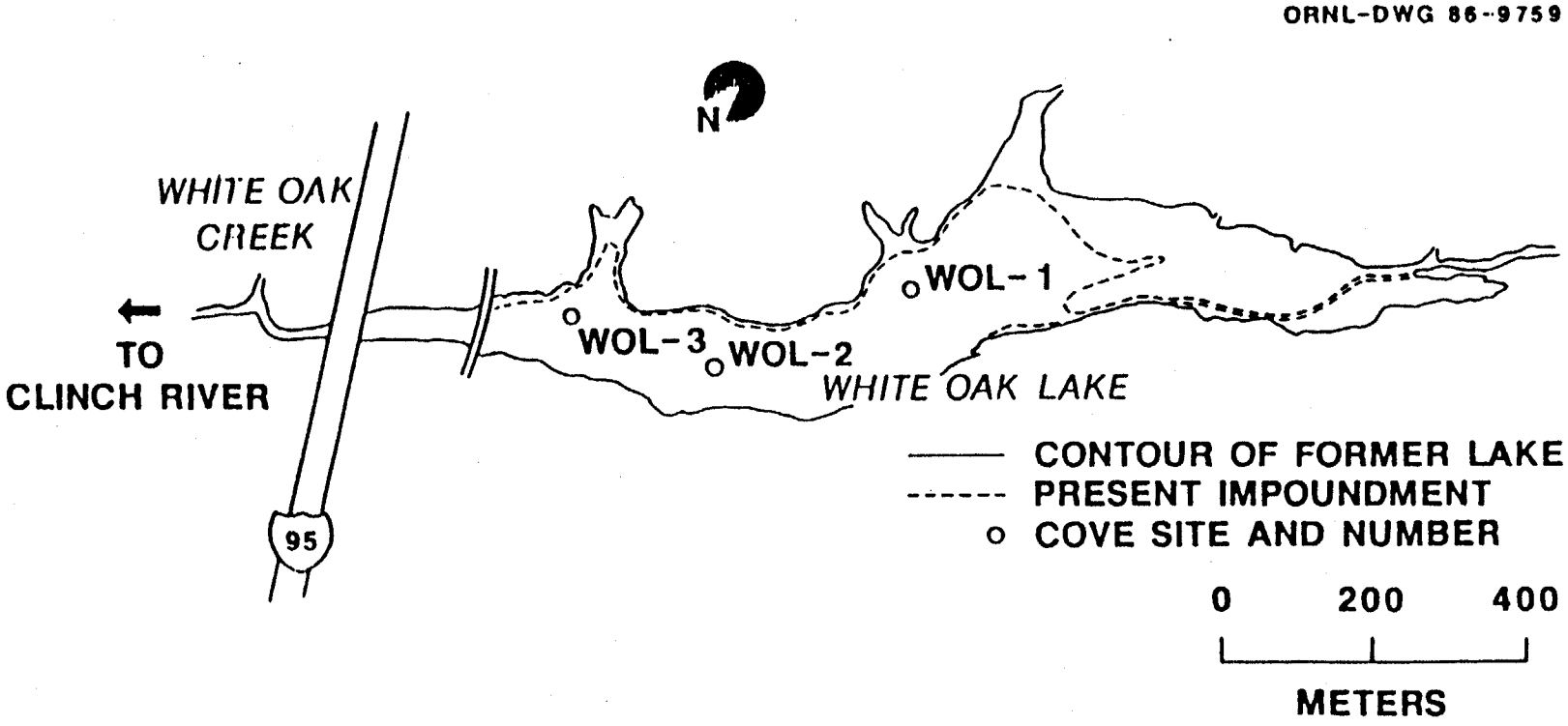

Figure 6. Map of White Oak Lake indicating the approximate locations of core sampling.

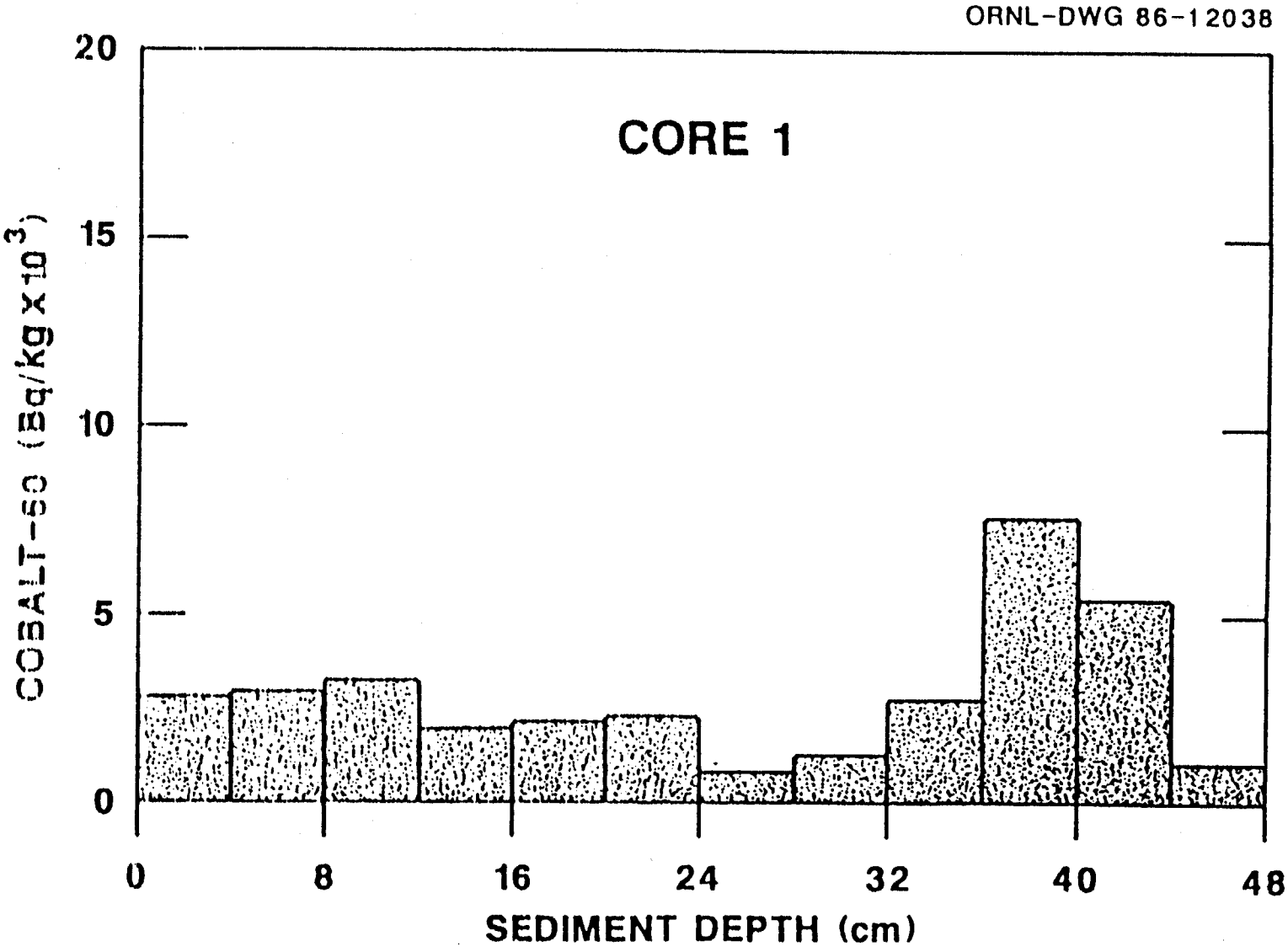

Figure 7. Cobalt-60 concentrations in White Oak Lake sediments, Core 1.

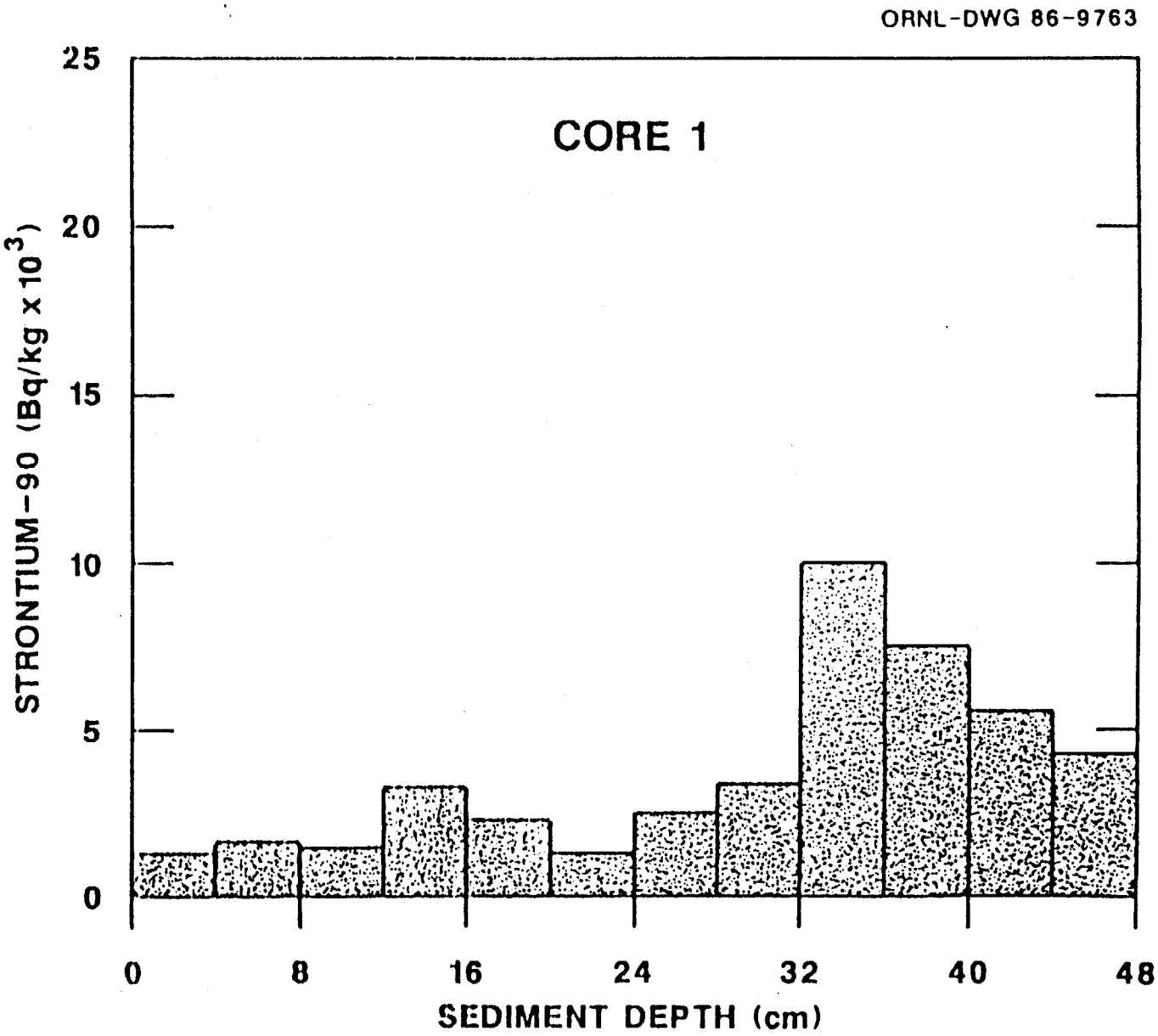

Figure 8. Strontium-90 concentrations in White Oak Lake sediments, Core 1.

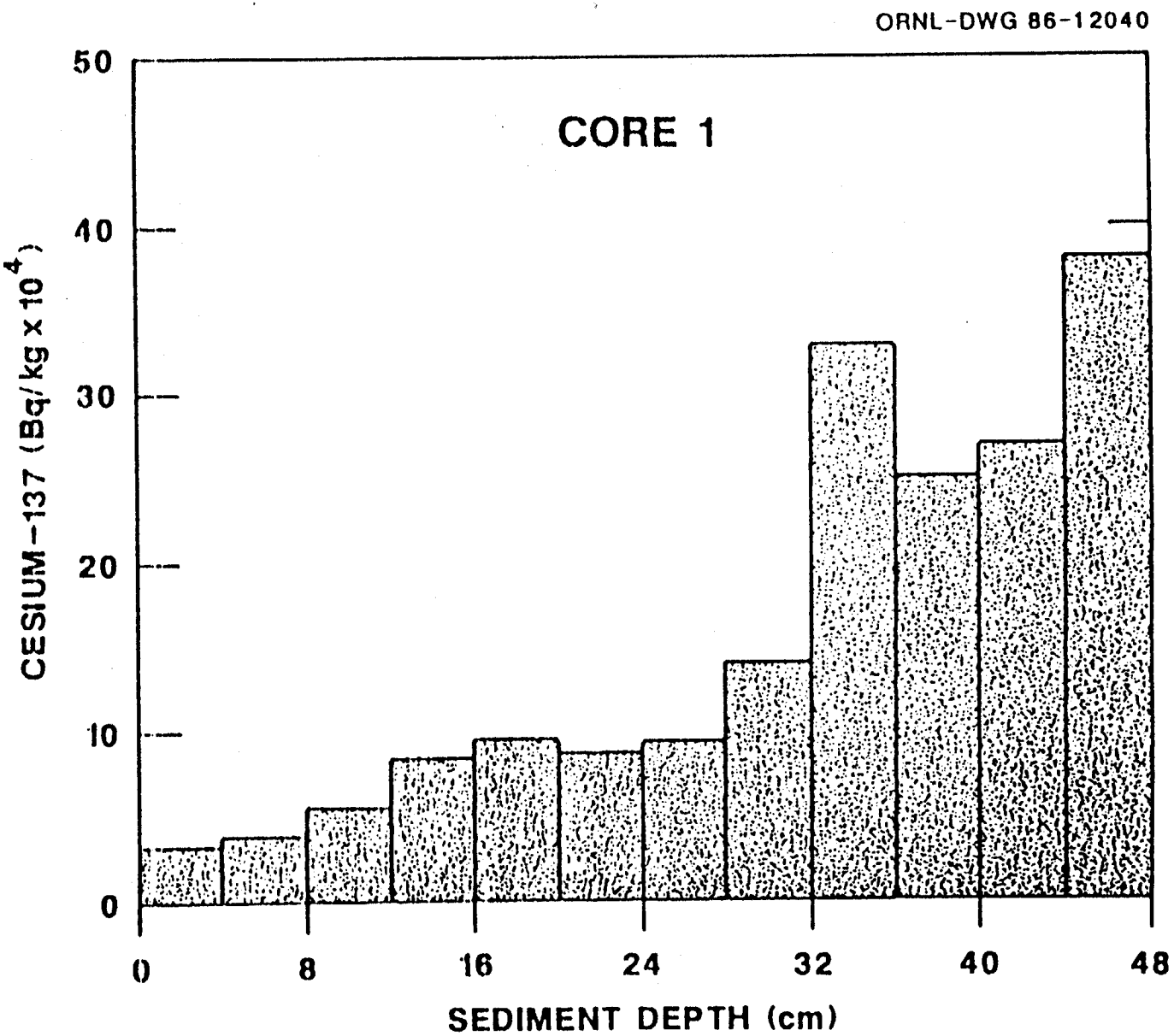

Figure 9. Cesium-137 concentrations in White Oak Lake sediments, Core 1.

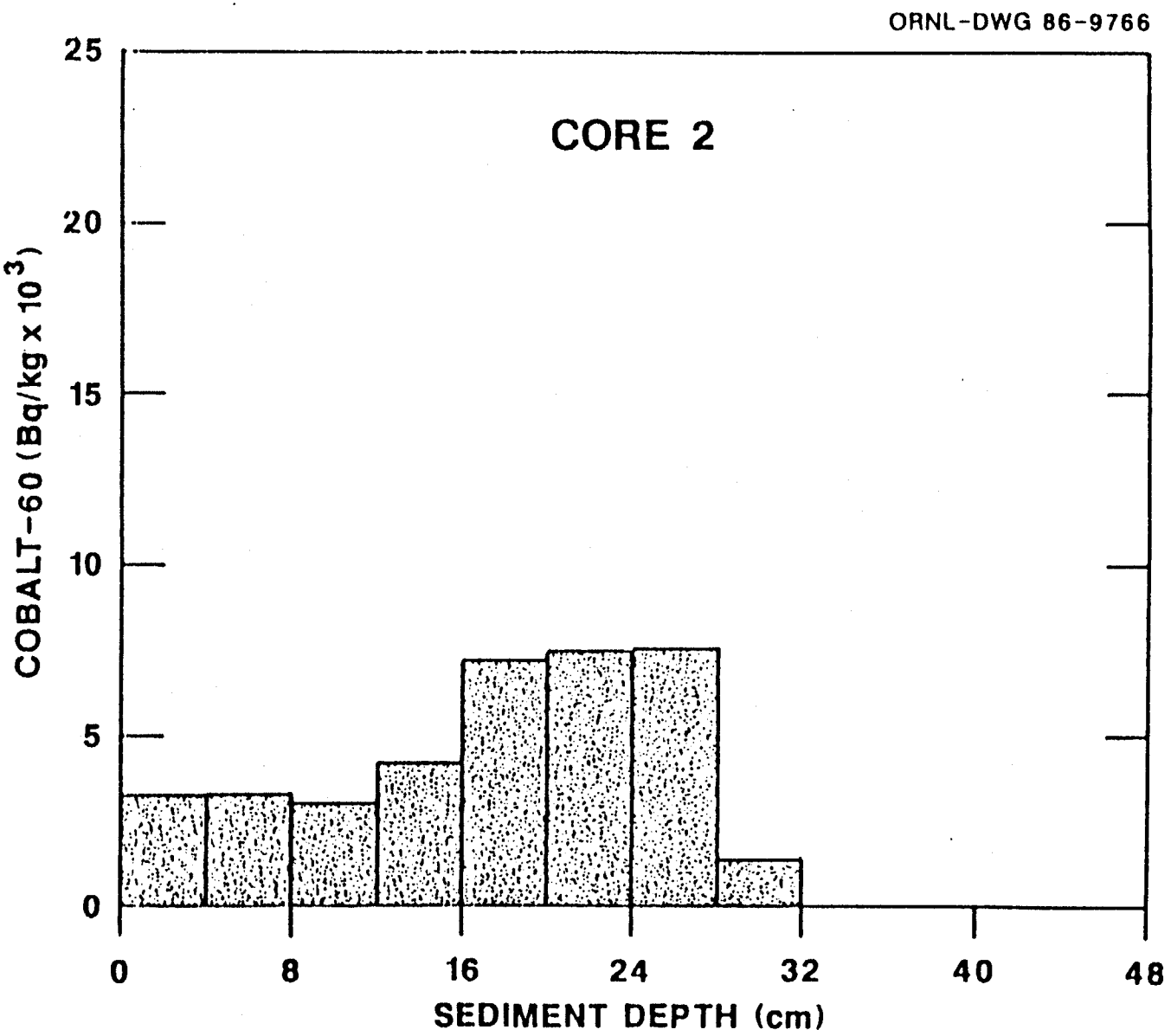

Figure 10. Cobalt-60 concentrations in White Oak Lake sediments, Core 2.

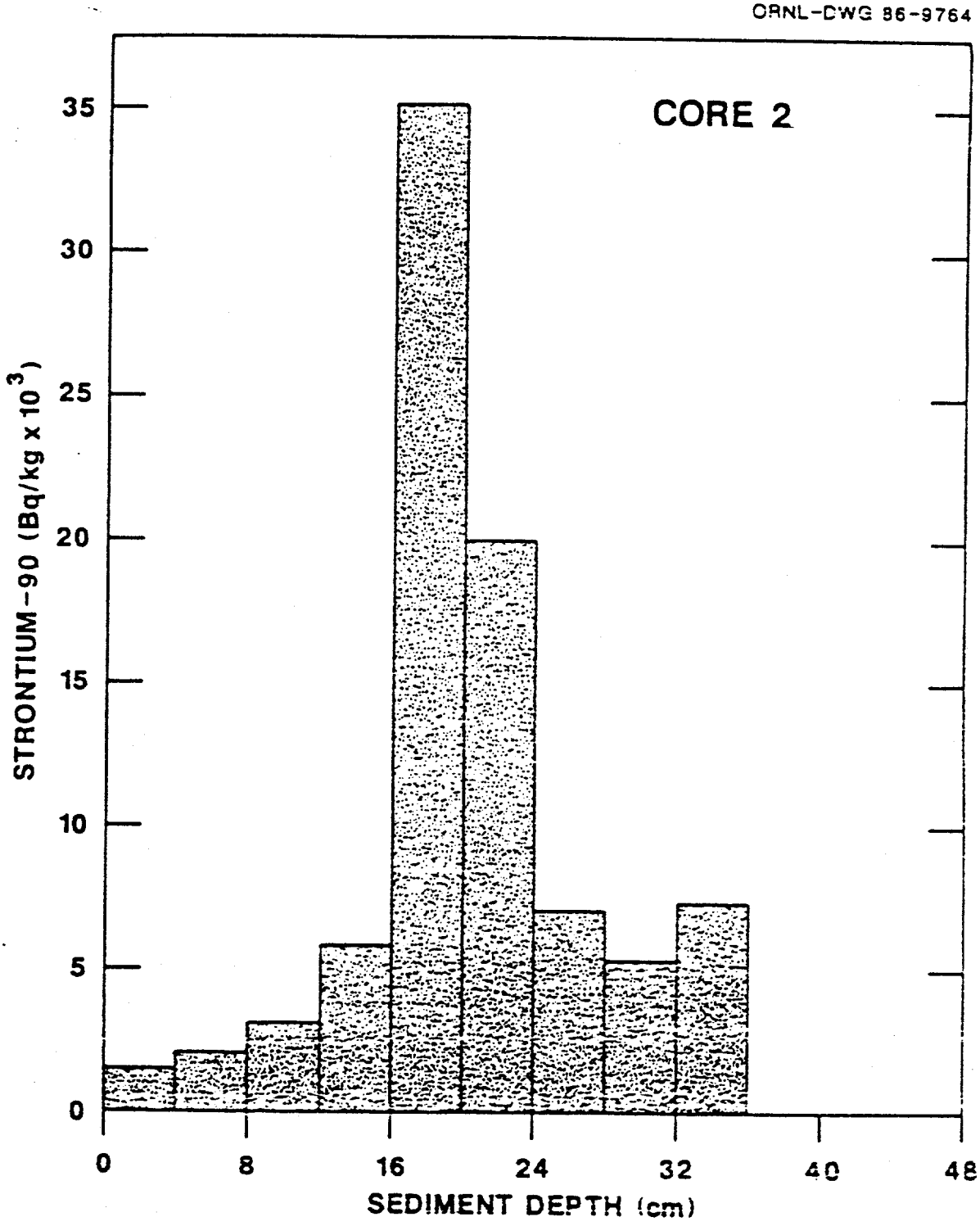

Figure 11. Strontium-90 concentrations in White Oak Lake sediments, Core 2.

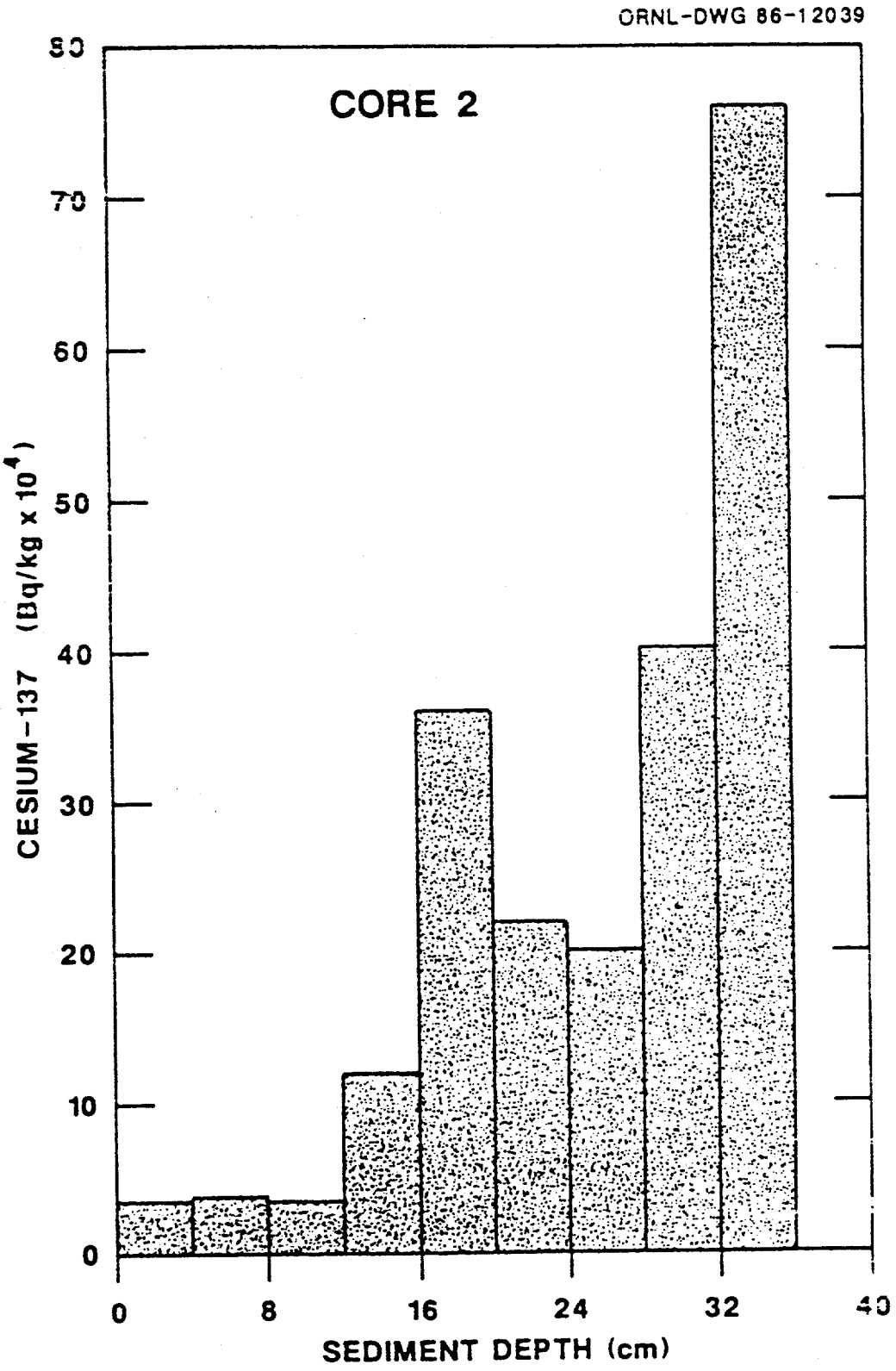

Figure 12. Cesium-137 concentrations in White Oak Lake sediments, Core 2.

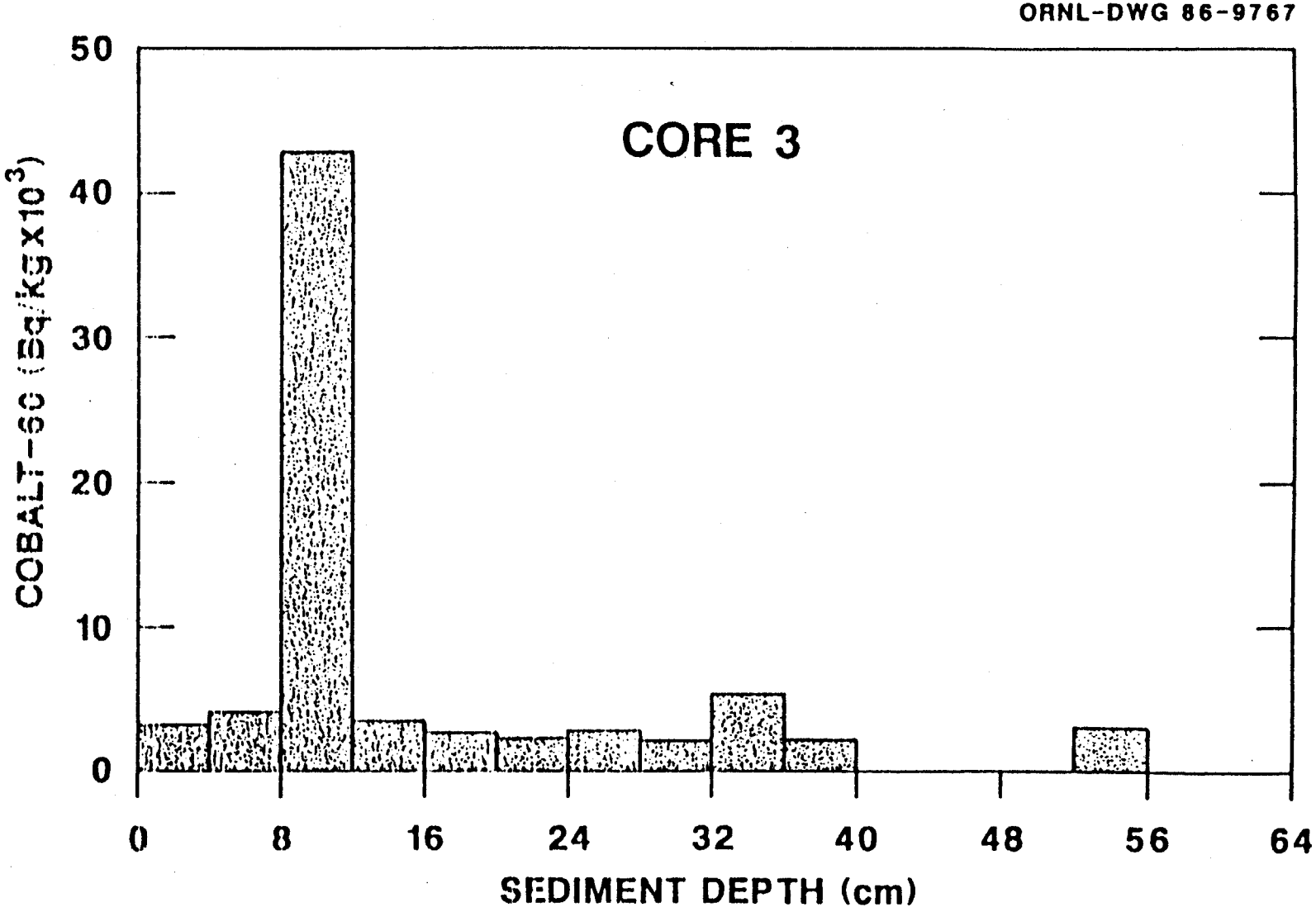

Figure 13. Cobalt-60 concentrations in White Oak Lake sediments, Core 3.

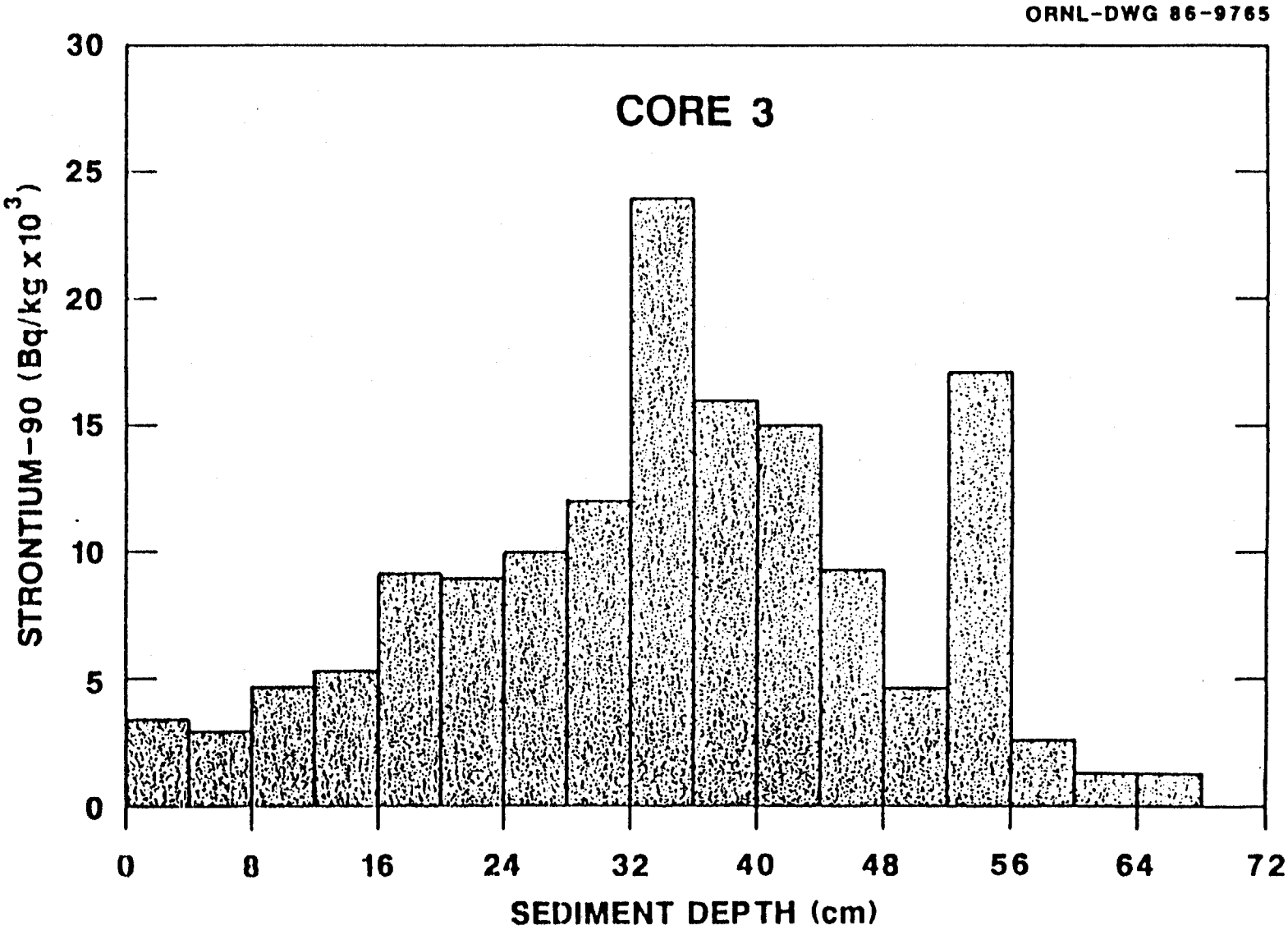

Figure 14. Strontium-90 concentrations in White Oak Lake sediments, Core 3.

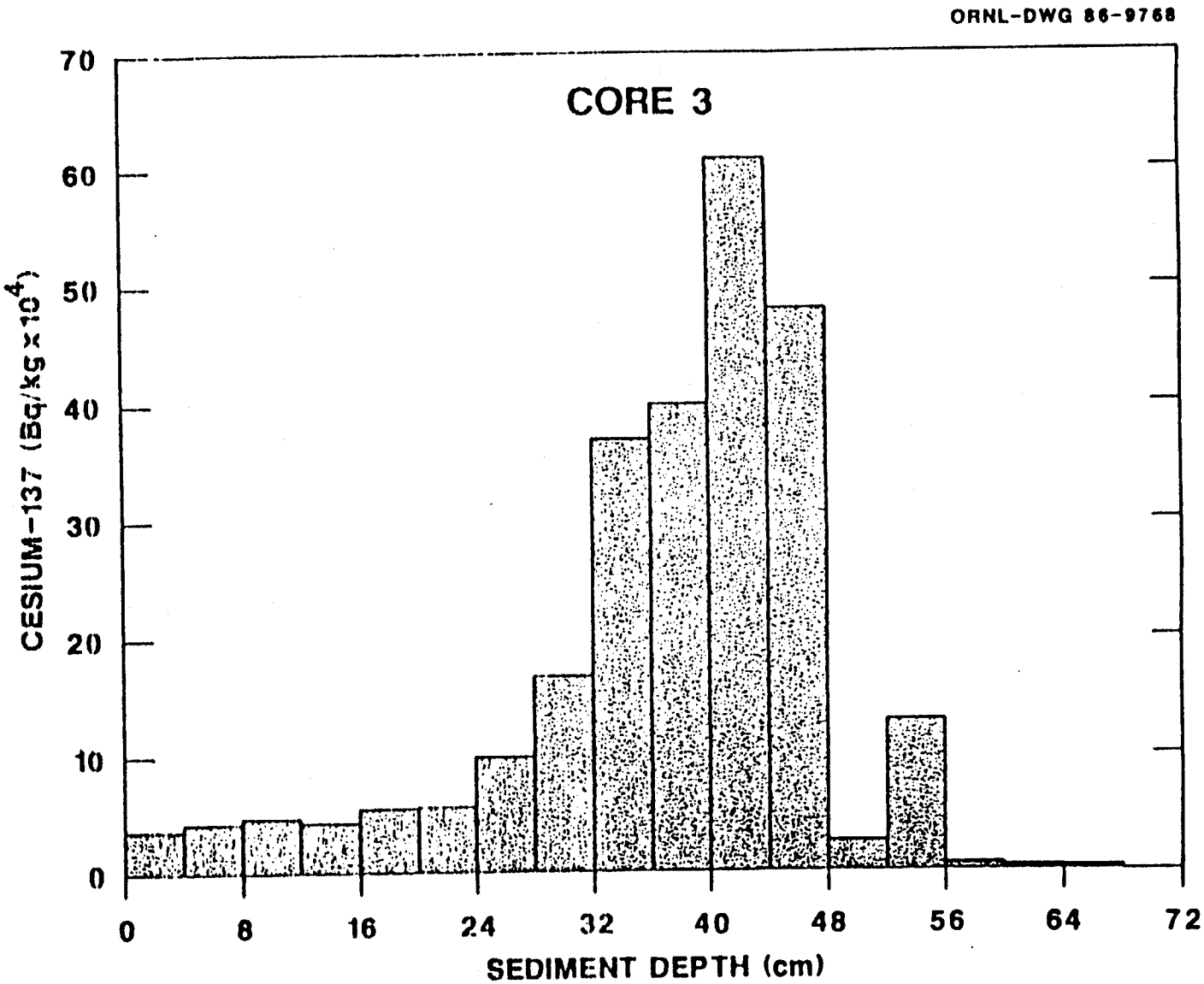

Figure 15. Cesium-137 concentrations in White Oak Lake sediments, Core 3.